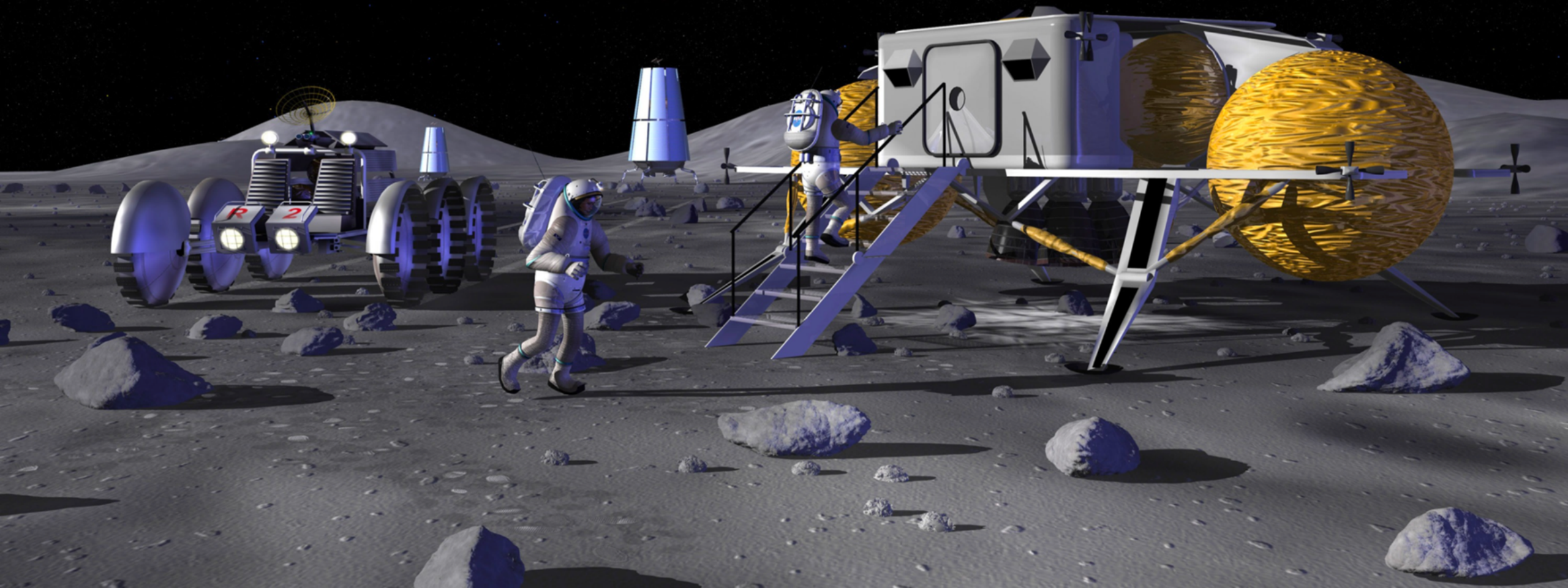


# NASA FDL: An AI Research Accelerator for Lunar Science and Exploration

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## Background -NASA Frontier Development Lab (FDL)



- **FDL is an applied AI research accelerator** that uses interdisciplinary teams to solve challenging problems for space science and exploration.
- **FDL is a PPP between NASA, SETI and the commercial sector** with key partners in AI/ML such as, Google, Intel, IBM, and Nvidia.
- **FDL is in its 4<sup>th</sup> year and has established an impressive success rate for research output.** Research outcomes are regularly accepted to respected journals and scientific conferences.
- **Over this time, FDL has developed 17 AI applications** in heliophysics, exoplanet discovery, lunar exploration, astrobiology, earth science and planetary defense.







# AI for Lunar Development and Exploration



**NASA FDL has a growing suite of AI tools for lunar development and exploration:**

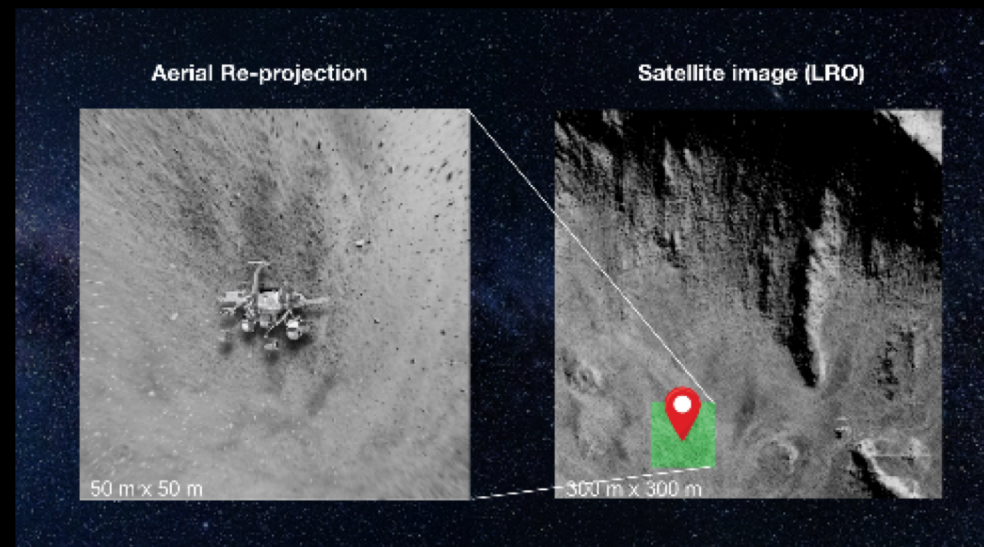
- Automated crater identification for lunar mapping
- Rover localization using onboard cameras
- Co-operative robotic methodologies for polar prospecting/traverse planning

**Challenges are chosen to identify closely with the National Space Exploration Campaign's strategic goals, specifically:**

- Lead the emplacement of capabilities that support lunar surface operations and facilitate missions beyond cislunar space

**Partners in FDL's past Lunar AI projects included:**

- Intel, Google and HP
- Luxembourg Space Agency/Space Resources
- XPRIZE Foundation





# Lunar Resource Mapping Challenge for 2019



## FDL Challenge

- It is estimated that billions of tons of metal (nickel-iron-cobalt) meteorite fragments could exist on the Moon. There also have not been any missions that specifically looked for evidence of M-class impactors.
- Impacts from meteors deposit metal on the lunar surface
  - Intact metal meteorites (as evidenced on Earth and Mars) would be a resource
- Determine the location of these metal meteorites so they can be used by future missions
- These lunar resources may be exploited through ISRU capabilities to build infrastructure on the Moon, such as lunar habitats.



Goal is to develop a high resolution lunar resource map to aid mission planners for robotic and human missions



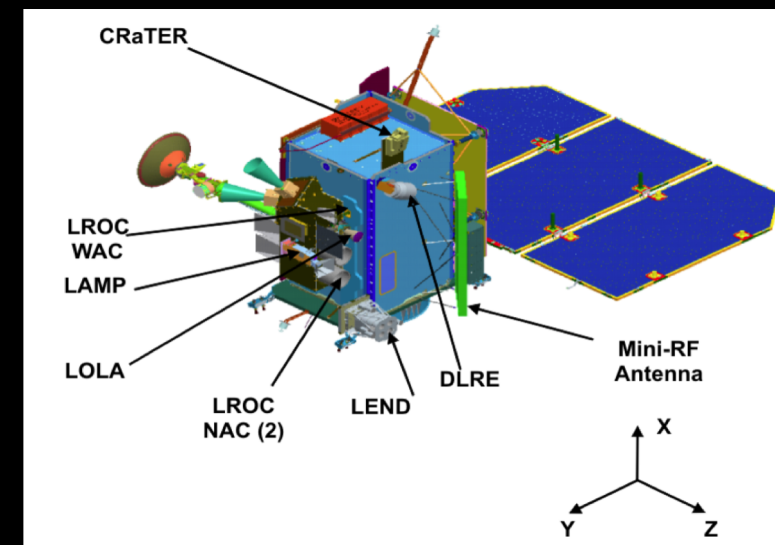


# Existing Lunar Mission Data



Several remote sensing lunar missions:

- Lunar Reconnaissance Orbiter:
  - WAC/NAC (UV/Vis), LOLA (altimeter), DIVINER (IR radiometer)
- Clementine (UV/Vis/IR)
- Gravity Recovery and Interior Laboratory (gravimeter)
- Lunar Prospector and Kaguya (magnetometers)
- Chandrayaan's Moon Mineralogy Mapper (spectrometer)
- Chang'e (microwave radiometer)

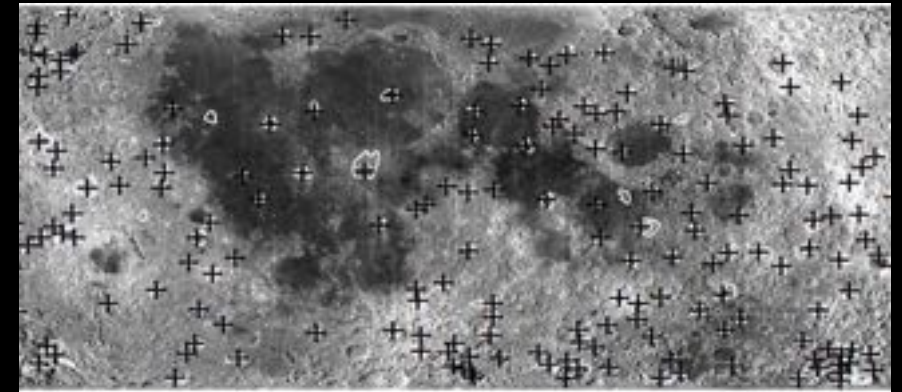




# FDL Lunar Challenge – Approach



- Generate a ML-ready, consistent datastack of all available data
- Use DIVINER data to create high resolution thermal anomaly maps
- Compare temperature anomalies to anomalies in other wavelengths
- Use unsupervised ML to identify correlations and anomalies



**Lunar Thermal Anomaly Distribution shows 266 hot/cold spots, from 60N to 60S (Zheng, et al, 2014)**

Project Goal: Identify potential metal signatures by fusing existing datasets and using AI to search for new correlations and anomalies.





# Lunar Development Lab (LDL) for 2020

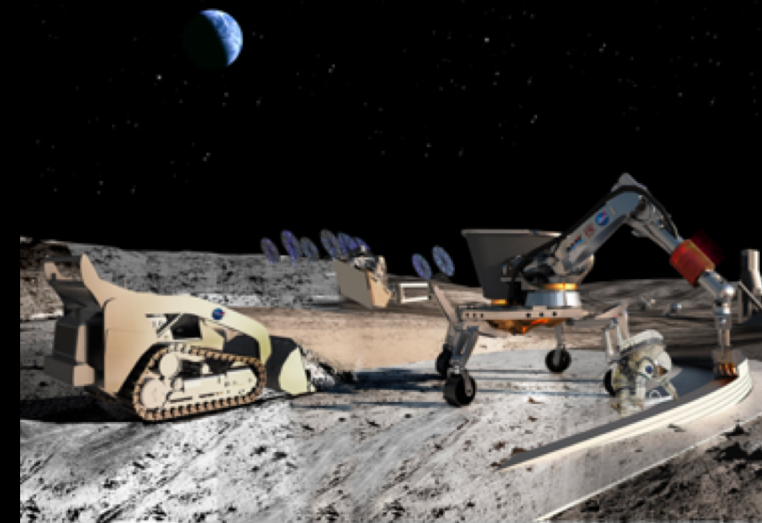


## Purpose:

- To bring together experts from academia, industry and NASA in an accelerator environment to advance lunar development sufficiently that leads to a **sustainable and economical human lunar outpost** as well as the **creation of a new thriving, cislunar economy**.

## Approach:

- **Generate** new design solutions, technologies and architectures leveraging lunar resources as much as possible.
- **Develop design solutions and architectures for infrastructure systems** including power generation and storage, communications, navigation, surface mobility and life support systems
- **Build and test prototype hardware** in a simulated environment to reduce technical and operational risk.
- **Use AI and machine learning technologies** and other advanced tools to quickly process data and optimize design solutions
- **Use economic analysis tools to compare designs and architectures** to work towards economic and sustainable solutions





## Draft Challenge Areas



1. **Lunar architecture designs** which integrate lunar resources into the design of surface systems, human habitats and life support systems.
2. **Infrastructure system designs** for power generation, communications, navigation, thermal management, landing pads and radiation shielding.
3. **Lunar mining techniques** and resource production estimates for key raw elements, e.g. H<sub>2</sub>O, O<sub>2</sub>, Si, Ti, Al
4. **High-definition lunar resource mapping** and modelling of minerals, metals and rare-earth elements.
5. **Economic analysis of resource production techniques** and competing lunar architectures
6. **Lunar base radiation 'safe haven' architectures** which uses supercomputer simulations of lunar magnetic anomalies

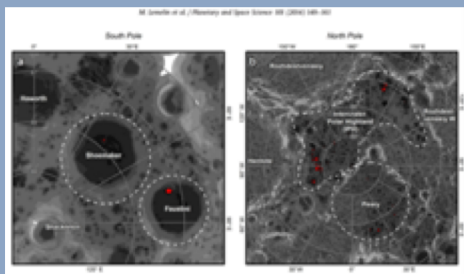
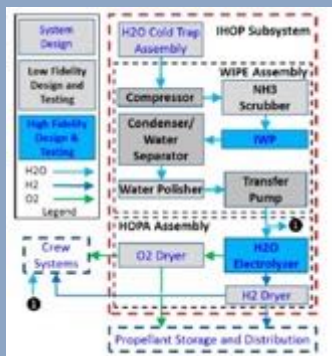






# Road From LDL to First Human Lunar Outpost

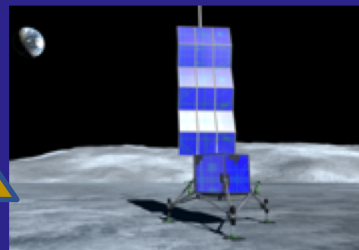
## Integrated Design Solutions



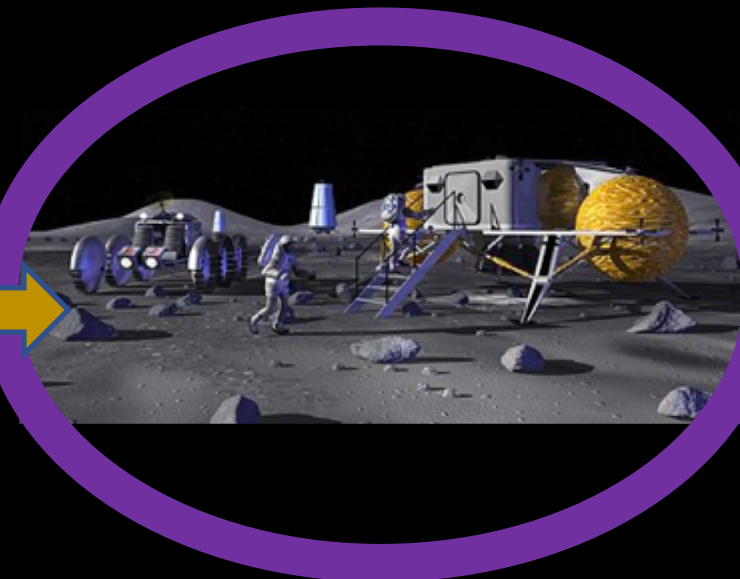
## Prototype Hardware and Ground Testing



## Low-Cost Flight Demonstrations



## Buildup of Initial Elements Human Lunar Outpost





## Next Steps



- **Define lunar resource challenge areas** for initial LDL 1.0
- **Establish public-private partnerships** to help sponsor teams in an accelerator environment
- **Select PI's to lead research objectives** challenge problems and technical team.
- **Solicit highly-qualified and motivated researchers and mentors** to participate in LDL 1.0
- **Prepare data and tools** that researchers will need to address challenge problems
- **Implement LDL research sprint sessions by FY 2020**





# THANK YOU!

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<https://frontierdevelopmentlab.org/2019-lunar-resources>

